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Applicants: William G. America

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Examiner: Im, Junghwa M.

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(IBMF-0058)

**Title: SEMICONDUCTOR DEVICE FORMED BY IN-SITU MODIFICATION OF
DIELECTRIC LAYER AND RELATED METHODS**

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

BRIEF OF APPELLANTS

This is an appeal from the Final Rejection dated March 24, 2008, rejecting claims 21-26.

This Brief is accompanied by the requisite fee set forth in 37 C.F.R. 1.17 (c).

REAL PARTY IN INTEREST

International Business Machines Corporation is the real party in interest.

RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences.

STATUS OF CLAIMS

As filed, this case included claims 1-20. Claims 21-26 are currently pending. Claims 21-26 stand rejected and form the basis of this appeal.

STATUS OF AMENDMENTS

No amendment has been submitted in response to the Final Rejection filed by the Office on March 24, 2008.

SUMMARY OF THE CLAIMED SUBJECT MATTER

The present invention provides a semiconductor device including a continuously deposited dielectric layer having different etch resistances through its depth. Specifically, differing etch resistances in the dielectric layer are obtained by modifying the composition of the dielectric layer during deposition of the dielectric layer. The disclosed device eliminates the depth and resistance variations inherent in time-based etch techniques and enables the deposition of a dielectric layer with varying etch resistances in a single deposition step.

Claim 21 claims a semiconductor device (*see, e.g.*, specification as filed, [0008], line 1; [0019], lines 1-2) comprising: a substrate (*id.*, [0019], lines 2-3; FIGS. 1-5B, item 10); a dielectric layer atop the substrate (*id.*, [0026], lines 1-3; FIGS. 3-5B, item 40 (atop item 10)), the dielectric layer (*id.*) including a first dielectric sub-layer (*id.*, [0019], line 2, FIGS. 1-5B, item 20), a second dielectric sub-layer (*id.*, [0020], line 6; FIGS. 2-5B, item 30) and a first non-discrete transitional dielectric sub-layer ([0020], line 8; FIGS. 2-5B, item 24) residing between the first and second dielectric sub-layer (*id.*, FIGS. 2-5B (item 24 located between items 20 and 30)), wherein the first dielectric sub-layer has an etch resistance different than the second

dielectric sub-layer (*id.*, [0020], lines 6-7); and an opening extending no deeper than the dielectric sub-layer nearest the substrate (*id.*, [0028], line 4-6; FIG. 5A, item 60); wherein the first dielectric sub-layer includes at least one component not included in the second dielectric sub-layer (*id.*, [0020], lines 1-3), the at least one component including perfluoroalkylsiloxanes (original claim 4, line 4; claim 9, line 4; claim 12, line 4; *see also*, [0021]-[0022]); and wherein a composition of the first non-discrete transitional dielectric sub-layer varies gradually through thickness thereof from a first composition substantially the same as the first dielectric sub-layer where the first non-discrete transitional dielectric sub-layer contacts the first dielectric sub-layer to a second composition substantially the same as the second dielectric sub-layer where the first non-discrete transitional dielectric sub-layer contacts the second dielectric sub-layer ([0020], lines 8-13).

GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

1. Claims 21-26 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Smith et al. (US Pat. No. 6,255,233, hereinafter, “Smith”) in view of Todd (US Pat. No. 6,733,830, hereinafter, “Todd”).

ARGUMENT

1. REJECTION OF CLAIMS 21-26 UNDER 35 U.S.C. § 103(a) OVER SMITH IN VIEW OF TODD

Appellant submits that Smith and Todd do not teach or suggest each and every feature of claims 21-26. Accordingly, Appellant submits that the rejection of claims 21-26 under 35 U.S.C. § 103(a) over Smith in view of Todd is defective. Reversal of the rejections is respectfully requested.

In the above-referenced Final Office Action, the Examiner admits that Smith does not teach the feature of “wherein the first dielectric sub-layer includes at least one component not included in the second dielectric sub-layer, the at least one component including perfluoroalkylsiloxanes” (claim 21, lines 8-9), but alleges that Todd teaches the same. (Final Office Action, p. 3.) Specifically, the Examiner asserts that “Todd discloses the first dielectric sub-layer includes at least one component not included in the second sub-layer, that is, the first dielectric sub-layer being fluorinated through the at least one component being selected from a group consisting of perfluoroalkyl [sic] group, therefore, forming perfluoroalkylsiloxanes [sic] (col. 9, lines 14-56).” (*Id.*) The cited passage, however, recites:

Primary chemical precursors have one or more preferred features that facilitate the formation of a low-k film or that provide the resulting film with one or more desirable properties. Preferred primary chemical precursors include:

1. Siloxanes of the formula $(R_3Si)_2O$ where each R is independently H, D, F, methyl, ethyl or propyl, preferably in which at least one R is F, methyl or ethyl, more preferably $H_3SiOSiH_3$, $H_3CSiH_2OSiH_2CH_3$, and $F_3SiOSiF_3$.
Siloxanes contain oxygen atoms and thus can be used without a separate source of oxygen. Preferred siloxanes such as $H_3SiOSiH_3$ and $F_3SiOSiF_3$ do not contain any C--H bonds, which tend to be more difficult to eliminate thermally at low reaction temperatures. Films resulting from siloxanes that contain fluorine atoms tend to have lower dielectric constants. Siloxanes are preferred precursors

for thermal CVD at temperatures in the range of about 300° C. to about 700° C.

2. (Fluoroalkyl)fluorosiloxanes of the formula $[(R_f)_{3-x-y}R^1_xF_ySi]_2O$ where R_f is a perfluoromethyl, perfluoroethyl or perfluoropropyl group, R^1 is H or D, x is 0 or 1, y is 1 or 2, and $x+y=1$ or 2, preferably in which R_f is trifluoromethyl, more preferably $F_3CSiF_2OSiF_2CF_3$ (Fluoroalkyl)fluorosiloxanes contain oxygen atoms and thus can be used without a separate source of oxygen. They also contain fluorine atoms which tend to result in films having lower dielectric constants. Preferred (fluoroalkyl)fluorosiloxanes do not contain any C--H bonds, which tend to be more difficult to eliminate thermally at low reaction temperatures. (Fluoroalkyl)fluorosiloxanes are preferred precursors for thermal CVD at temperatures in the range of about 300° C. to about 700° C.

3. (Fluoroalkyl)silanes of the formula $(R_f)_{4-a}SiR^1_a$ where R_f is a perfluoromethyl, perfluoroethyl or perfluoropropyl group, R^1 is H or D, and a is 0, 1, 2, or 3, preferably in which R_f is trifluoromethyl, more preferably F_3CSiH_3 ; (alkyl)fluorosilanes of the formula $R^2_{4-b}SiF_b$ where R^2 is methyl, ethyl or propyl, and b is 1, 2, or 3, preferably in which R^2 is methyl or ethyl, more preferably CH_3SiF_3 and $CH_3CH_2SiF_3$. (Fluoroalkyl)silanes do not contain oxygen atoms and thus can be used with a separate source of oxygen. They contain fluorine atoms which tend to result in films with a lower dielectric constant. Preferred (fluoroalkyl)silanes do not contain any C--H bonds, which tend to be more difficult to eliminate thermally at low reaction temperatures. (Fluoroalkyl)silanes are preferred precursors for thermal CVD at temperatures in the range of about 300° C. to about 700° C. (Todd, col. 9, lines 9-56.)

Thus, Todd relies on the use of various precursors, including siloxanes (col. 9, line. 13), (fluoroalkyl)fluorosiloxanes (*id.*, line 26), and (fluoroalkyl)silanes (*id.*, line 41), to facilitate the formation of a low-k film, or a resulting film with one or more desirable properties (*id.*, line 10-12). Appellant submits that Todd does not, however, teach or suggest using or forming a perfluoroalkyl group, or specifically, perfluoroalkylsiloxanes. (Request for Reconsideration, December 12, 2007, p. 4.)

Appellant further submits that even if, *arguendo*, Todd taught the use of a perfluoroalkyl group as a precursor, such use of precursors neither teaches nor suggests the feature of “wherein the first dielectric sub-layer includes at least one component not included in the second dielectric sub-layer, the at least one component including perfluoroalkylsiloxanes,” (claim 21) as Todd only discloses using the above-noted compounds as precursors, rather than disclosing an end product of perfluoroalkylsiloxanes included in a dielectric sub-layer. (Request for Reconsideration, December 12, 2007, p. 4.) In fact, Todd's use of precursors cannot predictably and controllably result in the claimed perfluoroalkylsiloxanes. (*Id.*, p. 4-5.)

Without further disclosure, a side product, if any, of the reaction between two precursors or between a precursor and a reagent would be unpredictable and uncontrolled, and would not enable reliable reproduction of the side product. (*Id.*) In addition, Todd does not disclose that perfluoroalkylsiloxanes are formed as a side product in a reaction taught by Todd. As such, Todd's disclosure, which does not teach the formation of perfluoroalkylsiloxanes, together with the knowledge in the art, does not support a conclusion that perfluoroalkylsiloxanes are inherently or necessarily produced where a perfluoroalkyl group is used as a precursor in the fluorination process of a dielectric sub-layer. (*Id.*, p. 5.)

In view of the foregoing, Appellant submits that Smith and Todd, either alone or in combination, do not teach the claimed invention including, in relevant part, a “first dielectric sub-layer includ[ing] at least one component not included in the second dielectric sub-layer, the at least one component including perfluoroalkylsiloxanes.” Accordingly, the Examiner has not proven a *prima facie* case of obviousness with regard to claim 21. Dependent claims 22-26 are believed to be allowable for the same reasons, as well as for their own additional features.

CONCLUSION

In summary, Appellant submits that claims 21-26 are allowable because Smith and Todd fail to teach each and every feature of the claimed invention, and because the cited references, taken alone or in combination, fail to meet each of the three basic criteria required to establish a *prima facie* case of obviousness.

Respectfully submitted,

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/Jayme M. Torelli/
Jayme M. Torelli
Reg. No.: 62,735

Hoffman Warnick LLC
75 State Street, 14th Floor
Albany, New York 12207
Phone: (518) 449-0044
Fax: (518) 449-0047

CLAIMS APPENDIX

Claim Listing:

21. A semiconductor device comprising:
 - a substrate;
 - a dielectric layer atop the substrate, the dielectric layer including a first dielectric sub-layer, a second dielectric sub-layer and a first non-discrete transitional dielectric sub-layer residing between the first and second dielectric sub-layer, wherein the first dielectric sub-layer has an etch resistance different than the second dielectric sub-layer; and
 - an opening extending no deeper than the dielectric sub-layer nearest the substrate; wherein the first dielectric sub-layer includes at least one component not included in the second dielectric sub-layer, the at least one component including perfluoroalkylsiloxanes; and wherein a composition of the first non-discrete transitional dielectric sub-layer varies gradually through thickness thereof from a first composition substantially the same as the first dielectric sub-layer where the first non-discrete transitional dielectric sub-layer contacts the first dielectric sub-layer to a second composition substantially the same as the second dielectric sub-layer where the first non-discrete transitional dielectric sub-layer contacts the second dielectric sub-layer.
22. The semiconductor device according to claim 21, wherein an etch resistance of the first dielectric sub-layer is greater than an etch resistance of the second dielectric sub-layer.
23. The semiconductor device according to claim 21, wherein the first dielectric sub-layer has a greater content of at least one of carbon and fluorine than the second dielectric sub-layer.
24. The semiconductor device according to claim 21, wherein the at least one component is selected from a group consisting of methylsilane, dimethylsilane, trimethylsilane, trifluoromethylsilane, 1,2-disilanotetrafluorethylene, 1,3-bis(silanodifluoromethylene)disiloxane, 2,2-disilanolhexafluorosilane, bis(trifluoromethyldisiloxanyl)difluormethane, octamethylcyclotetrasiloxane, and tetramethylcyclotetrasiloxane.
25. The semiconductor device according to claim 21, wherein the dielectric layer includes a third dielectric sub-layer residing between the substrate and the first dielectric sub-layer and a second non-discrete transitional dielectric sub-layer residing between the third dielectric sub-layer and the first dielectric sub-layer.
26. The semiconductor device according to claim 25, wherein the second dielectric sub-layer and the third dielectric sub-layer have substantially the same etch resistance.

EVIDENCE APPENDIX

No evidence is entered and relied upon in the appeal.

RELATED PROCEEDINGS APPENDIX

No decisions rendered by a court or the Board in any proceeding are identified in the related appeals and interferences section.